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TITLE BOREHOLE INSPECTION SYSTEM FOR LARGE DIAMETER HOLES

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BOREHOLE INSPECTION SYSTEM FOR LARGE DIAMETER HOLES

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ABSTRACT

A color camera developed for underwater applications has been adapted for use as a large diameter Borehole Inspection System (BIS). This video/photographic system has pan and tilt capabilities and remotely interchangeable lenses. A compass provides an azimuth for orientation. It is designed to operate in boreholes ranging in diameter from 1.2 m to 3.0 m. The system has a 180 degree "fisheye" lens and an inspection lens with zoom. 35 mm photographs can be taken of the same view as the video for precise location. Video tape and 35 mm film is annotated.

The primary function of the BIS is geologic investigation. Various characteristics of the geologic medium can be viewed. Lithologic types and textures can be determined. Structural features such as faults, fractures, and bedding can be scrutinized. Detail descriptions of stratigraphic sequences and contacts are possible. In combination with other borehole data and sample information, many questions about hole conditions and the geologic medium can be resolved. Field operations often demand immediate resolution of borehole problems. This system offers on-the-spot visual inspection of the drill hole and associated hardware. Large eroded zones can be evaluated and casings and liners can be inspected. Other applications such as the location and configuration of hardware left in the hole and fluid entry points are possible.

I. INTRODUCTION

The Borehole Inspection System was developed to examine large diameter drill holes at the Nevada Test Site (NTS). The goal was to get immediate information from the video and obtain 35 mm color slides for later, more detailed analysis. A "fisheye" lens was chosen to provide a complete view of the hole when directed downward. An inspection lens with zoom would be used for close up work. The lenses had to be remotely interchangeable to allow a complete inspection with one downhole run. Slide photography would be taken through the same lens as the video for precise location. Compass orientation had to be provided. Versatile annotation on both video tape and slides for on-the-picture data was a requirement to facilitate later viewing. Continuous recording of narration had to be possible on the video tape.

II. CAMERA SYSTEM

An "off the shelf" underwater camera with lens switching capability was adapted for borehole use (Fig. 1). A full 360 degree view of the borehole is achieved with the "fisheye" lens (when oriented downward) to obtain a visual record of the entire hole. The 35 to 70 mm zoom lens provides undistorted detailed views. Pan and tilt adjustments allow complete flexibility in camera orientation. Over 200 slides can be taken during a logging run. Each slide exposure requires approximately twenty seconds. A ruggedized compass gives the azimuth. Lens selection, zoom adjustment, pan

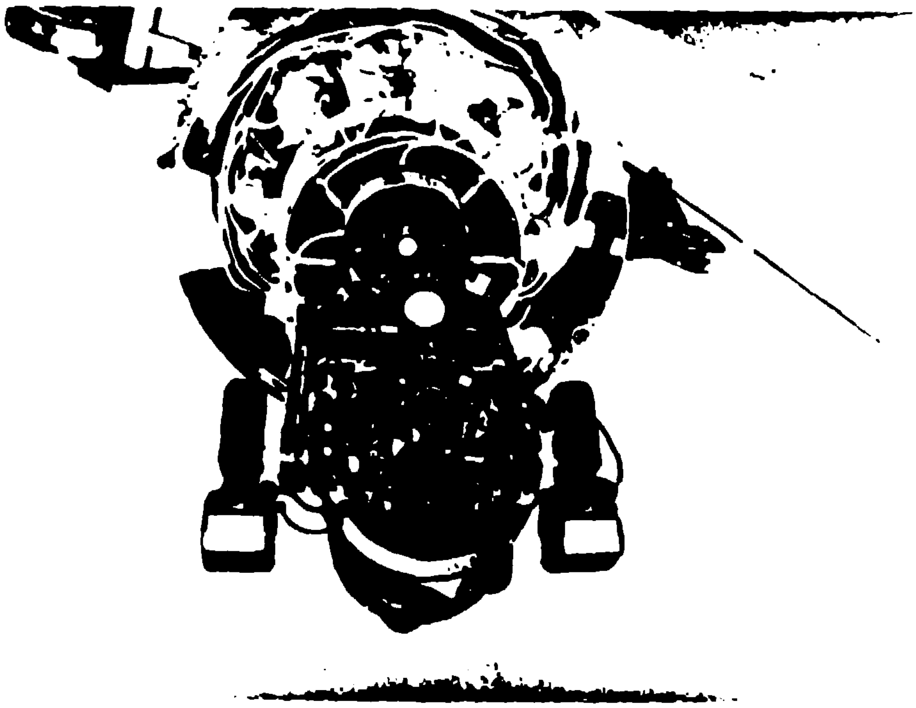

Fig. 1 Camera and lighting system.

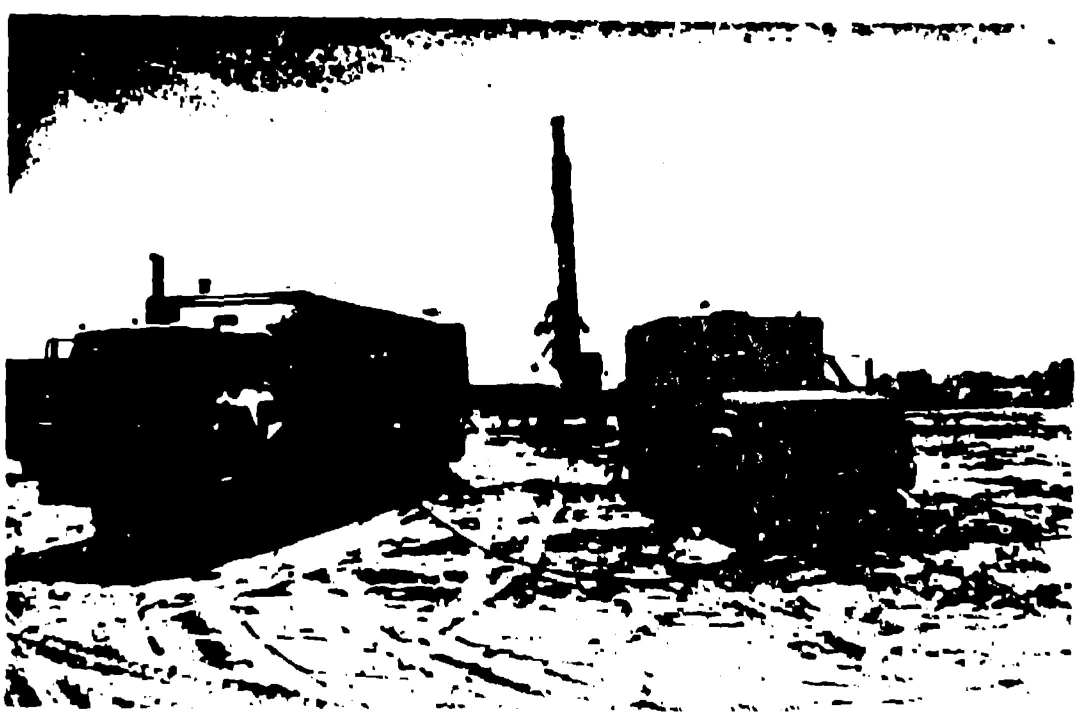

Fig. 2 Wellhead system; winch truck, and control/monitor van.

and tilt, and focus and f-stop settings are all controlled from the surface. In the inspection lens mode the zoom can be adjusted. Information can be inserted on the video tape with a keyboard. A clear plastic shield protects the face of the camera.

III. LIGHTING

Lighting for the video is provided by eight evenly spaced, 250 watt tungsten halogen lamps, mounted above the camera beneath a stainless steel reflector (Fig. 1). A protective shield is mounted above the reflector. Lamp intensities can be controlled from the surface either individually or as a unit to obtain various light/shade conditions. Considerable effort was expended in the development of the lighting system to avoid hot spots and shadows. Twin strobe flash units with interchangeable heads; and, flash quenchers for proper film exposure are mounted on either side of the camera. A spotlight pointer immediately above the camera provides additional illumination for greatly enlarged portions of a hole where the other lighting may not reach.

IV. BOREHOLE VEHICLE

The overall length of the subsurface vehicle is approximately 4 m. There are two sets of four individually adjustable legs to centralize the system in the hole. The legs are off center so each 0.25 m diameter wheel is tracking its own path on the borehole wall. Washouts and undergauge sections are traversed smoothly and concentrically. The system is currently set up to run in holes with diameters from 1.2 m to 3.7 m. The pan and tilt unit has a tilt range from -90 degrees (vertically down) to + 60 degrees and a full 360 degree pan. Downhole mechanical response to surface commands is smooth and precise. Mounted just above the camera is a lens defogger (heater fan). This allows defogging of the protective lens cover during the logging run, thus eliminating the need to pull the entire tool out of the hole to clear the view. The electronics is housed in the central tube of the vehicle where there is adequate room for future modifications. The tool is deployed on a special sixteen conductor wireline with a central 75 ohm coaxial cable, and a quick disconnect cablehead. Logging speed during a general survey is 12 m/min.

V. SURFACE SYSTEM

The wellhead system consists of the logging (winch) truck, a dual sheave crane assembly with load indicator and depth encoder, and the monitor/control van (Fig. 2). Power is provided by an on-site generator. The hydraulically controlled winch system contains over 1800 m of the custom designed logging cable. The winch operator's console is equipped with a video monitor to observe the same real-time image as the logging engineer who is directing the operation from the monitor/control van. Winchman and logging engineer are in constant radio communication. Transport and well site rig-up is facilitated through the use of a special transporter built specifically for the borehole vehicle. The camera is handled separately in a special container. Rig-up and quality assurance procedures require sixteen man hours.

The monitor/control van is equipped with three video monitors (Fig 3); a viewing monitor for the geologist, a data and control display monitor, and a preview/review monitor. The data and control information which can be displayed includes: lighting configuration, temperature in the electronics housing, telemetry status, compass heading, pan and tilt angles, and depth and load. Microprocessors and digital communication links are used for transmissions over the wireline. The preview/review monitor is connected to one of the two 3/4 inch U-matic audio-video cassette recorders (VCR) through an editor. Immediate playbacks; or, recordings of other nearby holes, can be viewed for comparison with the real-time video. The editor also provides the capability to record two tapes simultaneously, and allows on-site studio quality editing.

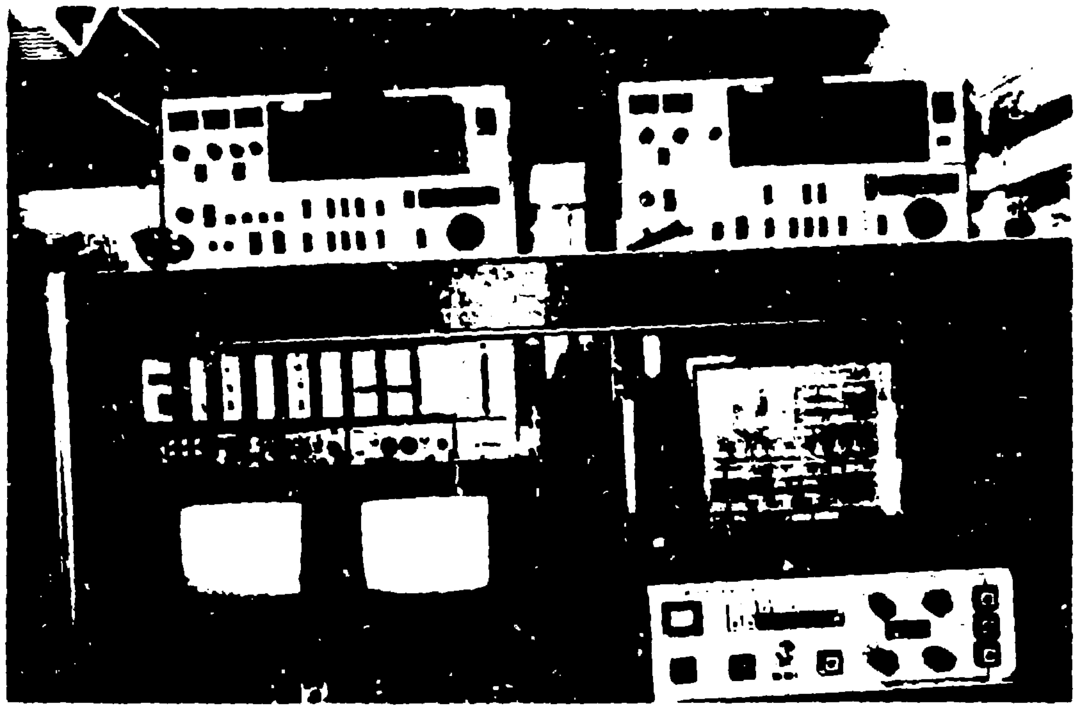

Fig. 3 VCRs and video monitors.

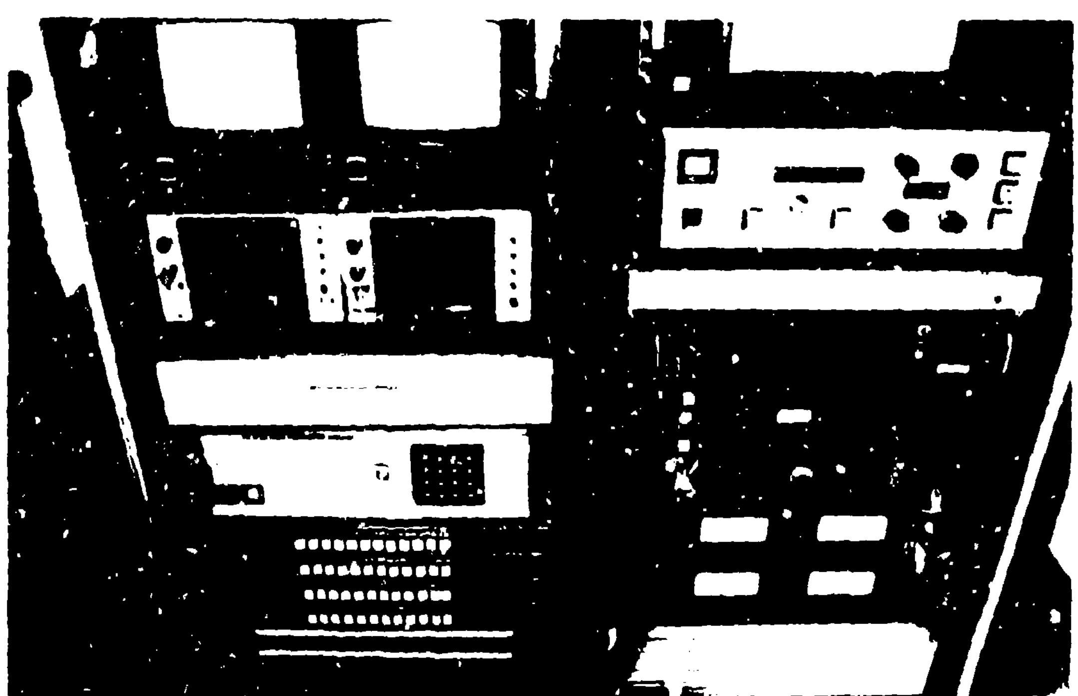

Fig. 4 Surface control system.

The surface control system (Fig. 4) which manages the various camera functions includes the camera pan and tilt controller, the power distribution panel, and the data acquisition controller. A routing and patching system enables complete versatility in routing any video signal to any VCR or monitor. The video equalization panel compensates the loss imposed on the base band video when run over the long wireline. Video color calibrations, trouble shooting, and wireline compensation adjustments are accomplished with a waveform monitor and vector scope, multiburst generator, and color bar generator.

VI. GEOLOGIC CHARACTERIZATION

The primary reason for developing the BIS is geologic characterization. Figure 5 is a fisheye view of a fault in U7by. The annotation, from left to right, across the top of the photo is: frame number, lens (8 designates 180 degree fisheye lens), date, hole, depth (in feet), azimuth, tilt and pan angle (degrees from reference point on frame for lighting adjustments). In the photo the fault has a trend of approximately north 30 degrees west with an easterly dip. A closer view of the fault with the inspection lens zoomed to the maximum 70 mm reveals more detail (Fig. 6). Note the changes in the annotation along the top of the photo. The view is looking to the southeast at an angle of 16 degrees down from horizontal.

The feature shown in Fig. 7 would probably not have been detected with normal borehole sampling and logging procedures. In the center of the frame is a thin (~ 0.15 m), nearly horizontal air fall tuff unit interstratified with alluvium (Drellack, et al, 1986). Because of the ability of the BIS to identify it, this bed has become a very useful marker unit within the alluvium of southern Yucca Flat. Geophysical logging techniques do not have the resolution to detect such a thin feature. Cuttings samples taken during the drilling are a mixture of material from a 3 m interval making it extremely difficult to characterize a feature of this thickness. At times there have been sidewall samples taken in this bed; but, until its presence was verified through photography in several drill holes, meaningful characterizations and correlations could not be made.

In U6d the moderately to densely welded ash flow tuff of the Topopah Spring member of the Paintbrush tuff (Fig 8) includes a 15 m thick lithophysal zone. The gamma-gamma density logging tool, which has to be in contact with the borehole wall to get reliable data, measured a 2.13 Mg/m^3 density for this zone (tool standoff eliminated 30% of the measurements). The gravimeter measured a formation density of 1.95 Mg/m^3 in the same interval. Although the difference is not great, an explanation based on the photography is obvious. The nature of lithologic zones such as a lithophysal layer which has large voids is important when considering the effects such a unit will have on phenomenology. Without the photography an accurate characterization of this zone would have been difficult.

Figures 9 and 10 are examples of operational concerns. A percussion gun sidewall sampling point is shown in Fig. 9. The sample cup which is explosively driven into the wall of the hole is approximately 0.03 m in diameter so the entire field of view for this photo, taken with the zoom inspection lens at 70 mm, is about 0.7 m across. The hole was drilled with a 2.44 m diameter bit. Roller stabilizers on the side of the bit made the diamond pattern in the mudcake left on the walls. Fig. 10 is the top of the liner at U4s. At times the nature of the liner cement job or fluid flowing over the top of the liner are of interest as are numerous other aspects of the transition from the open hole to the smaller diameter liner. Many questions about hole conditions can be easily answered with photography.

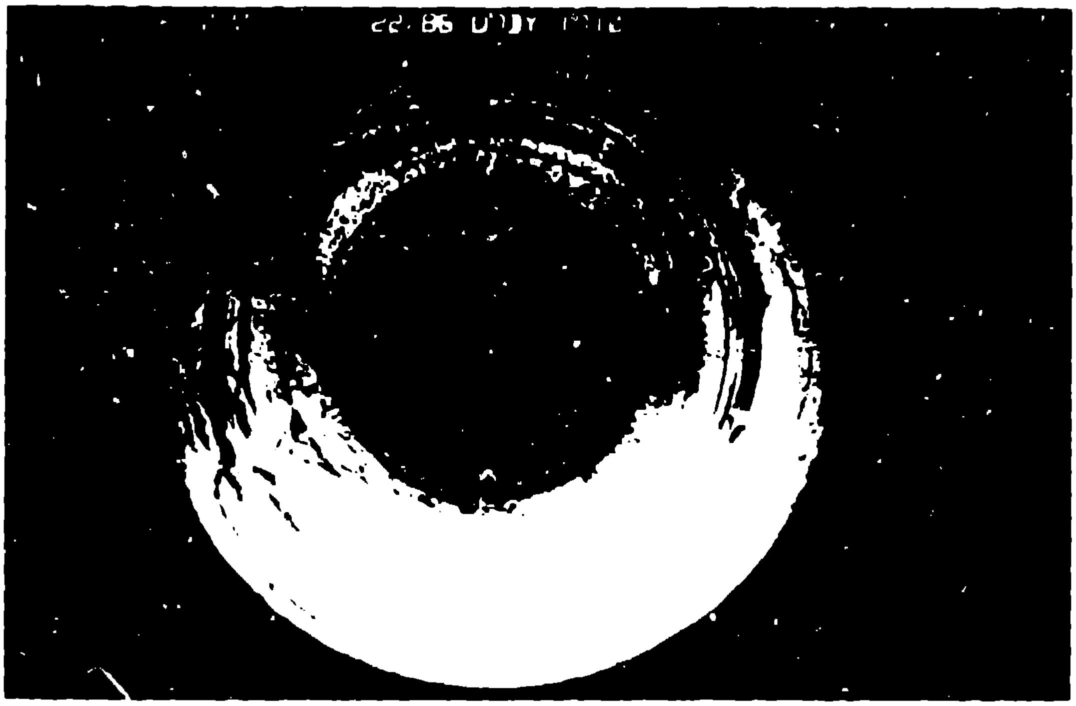

Fig. 5 Fisheye view of a small displacement fault.

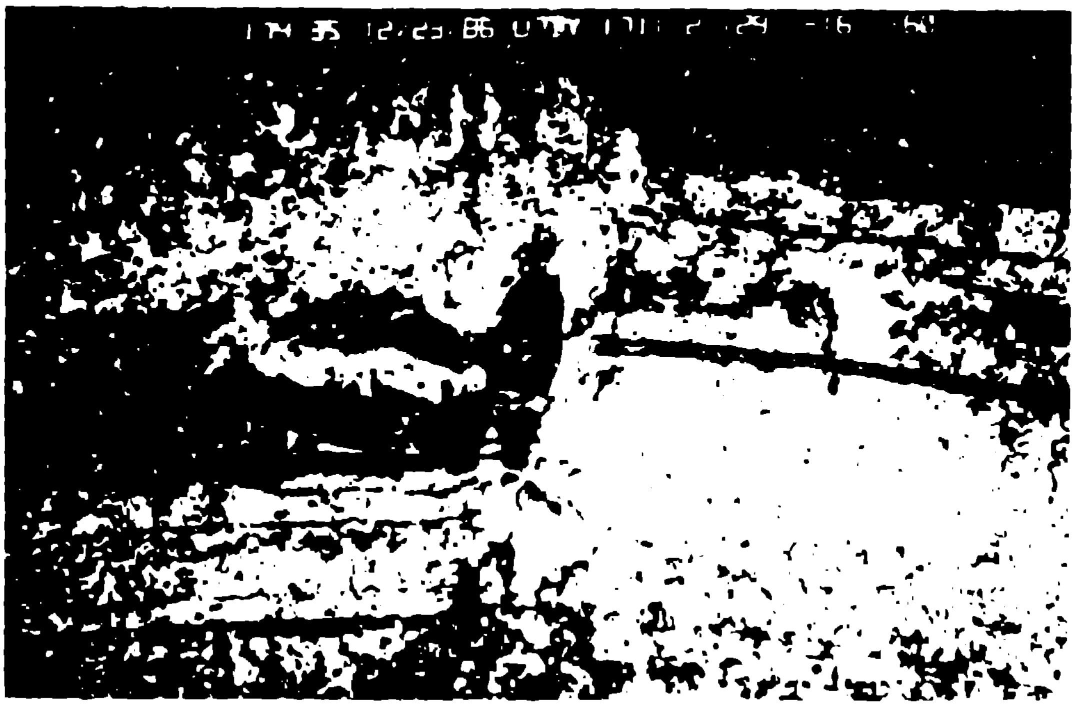

Fig. 6 Inspection lens view of the fault in Fig. 5

Fig. 7 Air fall tuff bed in alluvium.

Fig. 8 Lithophysal zone in a welded tuff.

Fig. 9 Percussion gun sidewall sample location.

Fig. 10 Liner top.

VII. SUMMARY

The development of the BIS has been invaluable in the assessment of borehole conditions at the Nevada Test Site. Immediate observations are made from the video for time urgent investigations. With a single deployment a complete, permanent color video and still photo record of the hole is made. The interchangeable lens system provides a general borehole survey in the fisheye and close up photography with the zoom lens for later detailed analysis. Geologic and operational features which would be difficult to characterize by other means can now be quickly and accurately assessed.

VIII. ACKNOWLEDGMENTS

The authors are grateful to their colleagues (too numerous to name appropriately) for their comments and suggestions which were crucial to the successful development of this tool and its applications.

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